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Effect of Sowing Methods and Intra-row Spacing on Growth and Yield of Three Varieties of Maize (*Zea mays* L.) at Gash scheme, Sudan.

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Abstract

Two field experiments were conducted at Kassala Research Station, Experimental Farm at Takroof, Gash Flush Irrigated Scheme, Kassala State, Sudan, during two successive winter seasons of 2015 and 2016, to study the effect of three Sowing methods namely: Ridge, Flat and local Farmer's Method, three Intra-row spacing 20, 30 and 40 cm on growth and yield of three grain maize (Zea mays L.) varieties, namely Hudeiba-1, Hudeiba-2 and variety113. The treatments of the experiments were conducted by using split plot arrangements based on a randomized complete block design with three replications, sowing methods were assigned as the main plots, the intra-row spacing as the subplots and maize varieties as the sub-subplost. The data were recorded for ten growth and yield characters during both seasons. The statistical analysis showed that sowing methods were significantly affected population density and hay yield during the first season and plant height during the second season. Ridge sowing method exclusively scored higher rates of all measured characters with exception of leaf length. Flat SM scored the highest level of grain yield during both seasons and they amounted (1732 and 1740 kg/ha, respectively). Statistical analysis of variance showed that population density, plant height, stem diameter, 100 seed weight, seed yield kg/ha and hay yield ton/ha were significantly affected by intra-row spacing during the first season. On the other side, leaf number and leaf area index were highly significantly affected by intra-row spacing during the second season. The space of 30 cm inter-row spacing scored the higher rates with respect to leaf number, leaf area index, stem diameter, 100 seed weight and seed yield Kg/ha. Statistical analysis revealed that population density, leaf number, 100 seed weight in and hay yield tons/ha were significantly affected by the varieties during the first season, leaf length during second season and Leaf area index during both seasons and all characters scored higher rates with respect to variety 113. Accordingly, Variety113, grown on ridge and with intra-row spacing of 20-30 cm gave the highest maize grain yield in Gash Scheme, Sudan.

Key words: Sowing Methods, Intra-row Spacing, Variety, Maize, Yield components

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I. INTRODUCTION

Maize (*Zea mays* L.) which belongs to the family Poaceae (Gramineae), is the third most important cereal crop after wheat and rice. Maize probably originated in the Highlands of South Mexico, from the highlands it spread to the low lands of Mexico and to other Central America Countries as reported by Spielvogel *et al.,* (2005). Maize is a monoecious crop with male and female flowers separated on the same plant. It is a highly cross pollinated, annual, short duration, long day and determinate crop (Hallauer and Miranda, 1988). Generally, maize is a multipurpose crop which has a wide range of uses than any other cereal crop where it can be utilized as human food, animal feed (grain or fodder). Maize has 4% fats, more than rice and wheat. The global production of maize reached 622 million metric tons in 2003-2004 (USDA-FAS, 2005) and increased to 785 million tons and about 158 million hectares of maize is harvested worldwide (FAO, 2015). The United States of America (USA) produces 42% of the global production and Africa produces 6.5% of it. The USA is the largest producer and in Africa, Nigeria is considered as the largest African country producer (produces nearly 8 million tons) followed by South Africa (FAO, 2015). Most maize production in Africa is produced under rain-fed conditions. The maize grain yield in Africa is about 1.3 T/ha compared to 4.0 T/ha elsewhere Sabo *et al.,* (2016).

In Sudan Maize is of a minor importance, it is grown in River Nile Banks, in small batches and in local system of farming called Jobraka, around houses in rural areas of South Kordofan State, in some irrigated schemes and in modern irrigation systems in Khartoum and River Nile states. Now days maize demand is increasing, due to the establishments of many Poultry and Dairy Farms. The high production of maize depends on the correct application of the technological bands of it, e.g. crop management, the distance between plants in a row, selecting the optimum sowing method that allow for ease field operations and minimize competition among plants for light, water and nutrients, in addition to the adapted cultivars, optimum harvesting time, marketing and financial resources (Dagash, 2012). Flush Irrigated Gash Scheme at Kassala State (East Sudan) with its most fertile soil in the world constitute a high potential to satisfy needs for maize in the Sudan. Hence the objective of this study is to investigate the effect of sowing methods, intra-row spacing on growth and grain yield of three varieties of maize.

II. MATERIALS AND METHODS

2.1 Plant materials and Experiment Description:

Three released open pollinated varieties of grain maize (*Zea mays* L.), obtained from Agricultural Research Corporation (ARC), Wad Medani, Sudan, were used in this study. Two experiments were conducted at Kassala Research Station Experimental Farm at Takroof location, latitude 15° 43' N and longitude 36° 38' East, elevation 596 m above sea level. The Gash soil analysis is presented in table, 3. The field experiments were carried out under irrigation system in the winter season for two consecutive seasons from September 2015 to January 2016 and from September 2016 to January 2017. (The climatic data of these periods are presented in table, 4). The experiments were carried to study the effect of sowing methods, intra-row spacing on growth and grain yield of three varieties of maize. The three sowing methods used in the study were ridging method (RM), flat method (FM) and farmer local method (FLM). The three intra raw spacing were 20, 30 and 40 cm between holes. The three grain maize varieties were Hudeiba-1, Hudeiba-2 and Variety113. The treatments of the experiments were conducted by using split plot arrangements based o a randomized complete block design with three replications, sowing methods were assigned as the main plots, the intra-row spacing as the subplots and the varieties as the sub-subplots. Land preparation was done according to ARC packages**.** The whole land of the experiment was ploughed using disc plough, disc harrow then leveled. For the sowing method treatment, three sowing methods were used included: the ridging method in which the space was 0.8 m between ridges, the flat method in which the land was leveled and divided into plots 3X3 meters area and the farmer local method (which is called the farmers' method in all Gash area), in which the plough was used to convert any three ridges to one area with 1 m apart. For

the intra-row method, the three varieties were sown in 20, 30 and 40 cm spacing between holes. After emergence of plants, seedlings were thinned to one plant per hill, resulting in about (62500, 41670 and 31250) plants per hectare. All cultural practices were applied during both seasons as recommended by ARC. No fertilizer and/or pesticides were applied. Hand weeding was executed at 2^{nd}, 6^{th} and 8^{th} weeks after planting to keep plots free of weeds. The irrigation was scheduled every two weeks interval. During growth period, population density/plot was recorded. At harvest time (when the plants reached physiological maturity) nine growth and yield traits were measured included: Plant height cm, Stem diameter cm, Leaf area index(LAI), number of leaves/plant , leaf length cm, leaf width cm, 100 seed weight, seed yield Kg/ha and hay yield Ton/ha.

2.2 Statistical Analysis

All the collected data of each season were analyzed separately, then the analysis carried out for each season using Statistics10 computer based program. Analysis of variance for each variable was attained and means were separated compared using Least Significant Difference (LSD) according to Gomez and Gomez, (1984).

III. RESULTS AND DISCUSSION

3.1 Effect of Sowing Methods on means of growth and yield components:

The effect of sowing methods on means of growth and yield are shown in Tables 1and 2. The statistical analysis showed that sowing methods were significantly affected population density and hay yield during the first season and plant height during the second season (tables 1 and 2). Ridge sowing method scored highest significant levels of population density and plant height, and scored the second level with respect to hay yield. Ridge sowing method exclusively scored higher rates of all measured characters with exception of leaf length and they amounted as the following: 2.0 and1.42 for LAI; 2.26 and 2.3 for stem diameter; 18.0 and 17.9 for 100 seed weight, and 11.8 Ton/ha for hay yield. Flat SM scored the highest level of grain yield during both seasons and they amounted (1732 and 1740 kg/ha, respectively). Meanwhile farmers' local method scored the second higher level with respect to grain yield during both seasons and they amounted (1626 and1578 Kg/ha, respectively). Mohammadein, (2005) reported that sowing fodder maize on flat SM resulted in higher final yield of dry matter at harvest. Ridge SM scored greater rates of 100 seed weight and hay yield during both seasons and they amounted 18.0 and 17.9 gm for 100 seed weight and 9.62 and 11.8 ton/ha for hay yield, respectively, table 2. Mohammadein, (2005) also reported that both ridge and mustaba* had no significant effect on all measured parameters, on the other hand ridge and flat were superior to mastaba in producing taller plants and leaf to stem ratio. Abass *et al*., 2010 reported that increasing population density caused significant decrease in stem diameter, a significant increase in LAI, fresh and dry weights of forage and dry weight of leaves. Amin, *et al.*, (2006), reported that maximum population density of 40000 plants/ha produced maximum number of grains/row (32.33), and grains/ear (447.3). However, 60000 plants/ha produced maximum number ears/plant of 1.33, maximum number of grains/row of 15.440, biomass yield of 16890 Kg/ha and grain yield of 2604 Kg/ha. Saberi *et al.*, (2014), reported that maize grain yield improved by planting methods, seed density and fertilizer level.

*A method of sowing used in the Sudan by joining two ridges together to form a platform has the same height of the ridge.

Table 1: Effect of sowing methods, intra- row spacing and variety on plant population density, plant height (cm), Leaf length (cm) leaf width of three maize (Zea mays L.) varieties

Treatment	Population Density		Plant Height cm		Leaf Length cm		Leaf number		Leaf Width cm	
S M	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Ridge	42.0	39.8	188.7	177.5	69.1	64.6	12.19	12.1	7.61	8.0

Flat	39.9	49.7	184.7	125.7	68.6	65.1	12.11	11.8	7.24	8.0
FLM.	31.2	37.7	186.2	167.2	69.4	65.8	12.07	11.8	7.40	7.8
LS	*	NS	NS	*	NS	NS	NS	NS	NS	NS
LSD0.05	2.708	13.45	5.211	3.909	8.212	8.212	0.546	0.668	0.386	0.831
Intra.R.S.										
20cm	48.1	40.5	178.5	155.9	69.1	66.5	12.04	11.86	7.36	7.8
30cm	36.1	45.2	189.8	158.9	66.7	64.5	12.9	12.2	7.60	8.0
40cm	28.5	41.5	191.2	156.4	69.1	64.6	12.15	11.6	7.39	7.8
LS	*	NS	*	NS	NS	NS	NS	*	NS	NS
LSD 0.05	3.048	4.713	8.770	1.197	3.285	2.519	0.576	0.442	0.297	0.282
Varieties										
Hudiaba1	37.4	42.9	184.2	155.6	69.6	66.5	12.11	12.0	7.49	8.0
Hudiaba2	36.8	41.8	185.3	157.7	66.7	63.5	12.13	12.0	7.45	7.8
Variety113	39.9	42.5	188.9	158.0	69.6	65.7	12.18	11.9	7.5	8.0
LS	*	NS	NS	NS	NS	*	*	NS	NS	NS
LSD 0.05	2.885	7.944	9.832	1.5809	2.768	2.520	0.392	0.430	0.342	0.364
Interaction										
SM*V	Ns	NS	NS	NS	NS	NS	NS	NS	NS	0.631
LSD	4.997	13.76	17.03	2.7382	5.695	4.363	0.679	0.744	0.592	NS
SM*S	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.488
LSD	5.279	8.165	15.19	1.0732	5.690	4.769	0.994	0.765	0.515	NS
V*S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD	5.279	8.165	15.19	1.0732	5.690	4.769	0.994	0.765	0.515	0.845
SM*S*V	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
LSD	9.144	14.14	26.55	3.5909	9.856	8.260	1.729	1.325	0.892	0.631

FLM=Farmer' Local Method, LS=Level of significant NS=not significant, *,**,*** significant to highly significant , LSD 0.05= Least significant difference at (P=0.05), SM*V=interaction between sowing method and variety, SM*S= interaction between sowing method and intra-row spacing V*S= interaction between variety and spacing, SM*S*V= interaction between sowing methods, IR- spacing and variety.

3.2 Effect of Intra-row Spacing on means of Growth and Yield components:

The nature of low or no tillers in maize crop necessitate the manipulation of population density to explore optimum inter and intra-row spacing which gave the optimum yield (Abass *et al*., 2010). The effect of intra-row spacing on means of growth and yield components are presented in tables 1 and 2. Statistical analysis of variance showed that population density, plant height, stem diameter, 100 seed weight, seed yield kg/ha and hay yield ton/ha were significantly affected by intra-row spacing during the first season as presented in tables 1 and 2. On the other side, leaf number and LAI were highly significantly affected by intra-row spacing during the second season as presented in tables 1 and 2. The space of 20 cm intra-row spacing scored higher levels of population density, leaf length, leaf number and hay yield as presented in tables 1 and 2. The space of 30 cm inter-row spacing scored the higher rates with respect to leaf number, LAI, stem diameter, 100 seed weight and seed yield Kg/ha as presented in tables 1 and 2. The space of 40cm intra-row spacing scored higher significant rate with respect to plant height, leaf number and insignificant level with respect to population density and plant height during the second season as shown in table 1. These results were in conformity with Montti *et al.*, (1974) who reported that highest grain yields were given in medium early hybrid grown at 7-8 plant/m^2 i.e. 12.5 - 14 cm intra row spacing. Hirose and Boesido, (1975) showed that early maturing cultivars required greater plant population to give optimum yield. Alessi *et al.*, (1976) reported that

maize hybrids grown at plant population of 20,000, 30000, 40000 and 74000 plants/ha in row 50-100cm apart, will have higher LAI, leaf area duration and stem diameters over whole season with higher population density, providing more time for grain filling and the ears require at least 7 weeks after silking to reach maturity.

3.3 The effect of Varieties on mean Growth and Yield components:

The main constraints to enhance maize productivity are the lack of specific production technology, the selection of unsuitable cultivar under a given set of environment is the major factor responsible for low yield and net income **(**Idris, and Mohammed, 2012). Leilah (2012), reported that for obtaining a high maize yield and net income maize cultivars had different responses to agronomic traits and grain yield. In this study, the effect of varieties on means of growth and yield components are shown in Tables 1and 2. Statistical analysis revealed that population density, leaf number, 100 seed weight in grams and hay yield tons/ha were significantly affected by the varieties during the first season, leaf length during second season and Leaf Area Index (LAI) during both seasons (Table,1 2). Variety113 achieved exclusively the highest levels with respect to population density, leaf length and leaf number characters (table, 1). While with respect to table 2, all characters scored higher rates with respect to variety 113. However, variety Hudeiba-1 scored the second and Hudeiba-2 was the least one. Alias *et al.,* (2010), reported that hybrids and varieties showed significant effect with respect to plant height, number of ears/plant, LAI, number of seeds/row, grain weight, and grain yield.

Table 2: Effect of sowing methods, intra- row spacing and variety on LAI, Stem diameter, Seed Yield, 100 Seed weight (gm) and Hay yield Ton/ha of maize (Zea mays L.).

Treatment	Leaf Area Index		Stem diam. Cm		100 seed weight		Seed yield Kg/ha		Hay yield Ton/ha	
S M	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Ridge	2.00	1.42	2.26	2.3	18.0	17.9	1547	1578	9.62	11.8
Flat	1.92	1.35	2.21	2.2	17.3	17.2	1732	1740.	10.0	9.96
FLM.	198	1.37	2.21	2.21	17.4	16.6	1626.	1578.	8.03	8.0
LS	NS	NS	Ns	NS	Ns	Ns	Ns	NS	*	NS
LSD0.05	0223	0.2125	8.212	0.247	1.297	3.760	212.1	541.4	1.157	5.062
Intra R.S.										
20cm	1.88	1.28	2.16	2.28	18.4	16.5	1500	1637	9.81	9.84
30cm	2.06	1.92	2.27	2.28	17.2	18.2	1767	1595	8.91	8.9
40cm	1.95	098	2.23	2.18	17.1	17.0	1640	1637	8.94	11.1
LS	NS	***	*	NS	*	NS	**	NS	*	NS
LSD 0.05	0.119	0.1032	0.069	0.135	0.92	2.018	155.91	267.9	0.843	3.702
Varieties										
Hudiaba1	1.93	1.36	2.22	2.22	17.4	16.4	1568	1625	8.0	10.13
Hudiaba2	1.97	1.35	2.20	2.21	16.5	16.7	1654	1525	8.62	8.65
Variety113	1.99	1.43	2.25	2.25	17.4	18.6	1683	1766	11.03	11.04
LS	*	*	NS	NS	***	NS	NS	NS	***	NS
LSD 0.05	0.108	0.0683	0.086	0.174	0.90	2.312	164.26	319.2	0.592	3.701
Interac.										
SM*V	NS	NS	NS	NS	Ns	NS	NS	NS	*	NS
LSD	0,1863	0.1162	0.149	0.301	1.024	4.004	284.5	551.1	1.026	6.701

SM*S	NS	NS	NS	NS	*	NS	NS	NS	*	NS
LSD	0.2045	0.1788	0.119	0.234	1.56	3.494	270.04	468.9	1.459	6.431
V*S	NS	NS	NS	NS	*	NS	NS	NS	*	NS
LSD	0.2045	0.1788	0.119	0.234	1.56	3.494	270.04	468.9	1.459	6.411
SM*S*V	NS	NS	NS	NS	Ns	NS	*	NS	***	NS
LSD	0.3562	0.2125	0.206	0.405	3.074	6.411	467.7	809.6	2.528	11.11

FLM=Farmer Local Method, LS=Level of significant NS=non-significant, *,**,*** significant to highly significant, LSD 0.05= Least significant difference at (P=0.05), SM*V=interaction between sowing method and variety, SM*S= interaction between sowing methods and intrarow spacing, V*S= interaction between variety and spacing, SM*S*V= interaction between sowing method , spacing and variety.

3.4 Effect of the interaction between the factors on means of growth and yield components:

Grain yield was not significantly affected by the interaction during both seasons with respect SM*V, SM*S, V*S and SM*V*S. while the other characters i.e. hay yield was significantly affected by the interaction between SM*V, SM*S, V*S* and SM*V*S. The combinations during 2015 of SM2*V3*S2 (Flat*Variety113*30cm) and SM3*V3*S3 (local farmer' method *Variety113*30cm) scored the high amounts grain in kg/ha, while during 2016 SM2*V3*S1 cm (Flat*Variety113*20cm) scored the high grain in kg/ha. Similar findings were reported by Amin, *et al.*, (2006).

IV. CONCLUSIONS

From the above obtained results, it could be concluded that, the ridge method affect positively most of the measured characters. The 30 cm intra-row spacing scored higher rates of grain yield of (1767kg/ha) followed by 40 cm intra-row spacing which scored (1640 kg/ha) grain yield. However, the variety113 scored higher rates of most of measured characters during both seasons. The interaction between the different factors in most cases significantly resulted in higher rates of most of the characters.

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Table 3: Gash Soil Analysis:

Soil name	PH	EC Dl/m-1	SAR %	ESP %	OC %	N ppm	P Ppm	K ppm	Sand ppm	Clay ppm	Silt Ppm
R1	8.1	o.83	1.2	1.9	0.20	340	2.4	37.5	9	37	54
R2	7.8	o.80	1.6	2.3	0.05	215	2.3	31.3	11	35	54
F1	7.9	1.1	2.1	3.0	0.05	401	2.3	37.3	12	39	49
F2	7.5	0.84	2.1	3.0	0.73	211	2.3	12.5	7	41	52

EC-Electrical conductivity, SAR=Sodium Absorption Ratio, ESP=Sodium exchangeable %, OC=Organic Carbon

Tabl 4: Climatic Data from September to January for 2015 and 2016 Season: min., maxi and mean temperature, R.H.%, Evaporation (Piche mm), R.F mm, Sunshine/day, Hours of Sunshine, Wind direction and speed.

Month	Maxi. Temp.	Mini. Temp.	Mean Temp.	Mean RH%	Evap. Piche mm	Rain Fall mm	Sun shine D.	Sunsh Hours /day	Wind Direction	Wind Speed Knots
Sept 2015	38.3	25.1	31.7	47	10.1	2.5	79	9.7	S	0.3
Sep. 2016	35.7	23.8	29.8	59	-	2.0	-	-	S..SW	03
Oct 2015	39.9	26.0	33.2	37	13.0	2.5	79	10.1	A.D.	03
Oct 2016	39.1	24.9	32.1	41	-	13.9	-	-	A.D	03
Nov 2015	38.1	23.5	30.9	37	12.9	0	92	10.5	N. N	03
Novr2016	38.1	23.0	30.8	33	-	Nil	-	-	E	03
Dec 2015	32.9	18.3	25.5	45	10.1	0	86	09.6	N.NW	03
Dec 2016	36.3	21.3	28.7	45	-	Nil	92	10.5	N.,NE	03
Jan 2016	34.1	16.9	26.0	42	11,4	Nil	90	10.1	N.	0.3
Jan 2017	33.4	16.6	29.8	42	10.7	Nil	86	9.8	NW	0.3